CIVIL ENGINEERING SOLUTIONS

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Location: 2244 NW Market Street, Seattle, WA 98107
Date: 2016.02.25 14:14:37 -08'00'

# Stormwater Technical Information Rep
# For Targeted and Large/Full Project Site

| | |
|---|---|
| **Project Name**: | Kirkland Cottages |
| Project Address: | 7845 NE 122nd Place<br>Kirkland, WA 98034 |
| Parcel Number(s): | 607650-0421 |
| Gross Site Area: | 42,028 sf (from KCiMap) |
| Estimated "New" Impervious:<br>(new = net increase) | 8,400 sf (>5,000 sf) |
| Estimated New + Replaced Impervious: | 15,300 sf (>10,000 sf) |
| Soil: | AgC (Alderwood gravelly sandy loam) |
| Name of Owner: | Chandler Homes<br>811 Kirkland Avenue, #201<br>Kirkland, WA 98033<br>(425) 885-3939 |
| Engineer: | Duffy Ellis, P.E.<br>Civil Engineering Solutions<br>2244 NW Market St., Suite B,<br>Seattle, WA 98107 |
| Phone Number: | 206-930-0342 |
| **Report Date**: | January 13, 2016 |

| This box to be completed by COK staff | |
|---|---|
| PERMIT # | |

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## Vicinity Map


## A. Project Overview

Subject 1.07-acre site is located on the south side of NE 122nd Place between Juanita Drive NE and 84th Place NE. Project proposes 5 buildings resulting in total of 10 Townhouse style dwelling units along with required infrastructure. Project is just north of Juanita Woodlands Park. It is in Kirkland's Finn Hill neighborhood, and is zoned multi-family residential.

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Some highlights of site in terms of drainage follow:

New Driveway across Champagne Creek
Champagne Creek passes thru property from east to west and parallel to NE 122nd Place. This is a mapped and delineated class B stream with 60 foot buffer requirement. A reduced buffer is proposed to allow development of site. A complete stream mitigation report by Bill Granger will address this along with the new open bottom culvert and driveway crossing off NE 122nd. This report will also be submitted to the State for the JARPA permit.The benefits of this new entrance was discussed by applicant and City Staff at pre-application conference (which I didn't attend).

Open bottom Culvert
We have run calcs for 100 year storm tributary to this section of creek using Q=CIA (Rational Method) and worked with the folks at contech to install an open bottom culvert to serve new driveway across the stream/creek. We do not propose any disturbance to the creek below the "ordinary high water mark" or OHWM. See all calculations in appendix of report. This will also be submitted to State for JARPA.

Stormwater Detention Required
A level 2 vault is currently proposed in compliance with Kirkland and King County Storm Requirements associated with Full Report. Vault will meet Level 2 sizing requirements using KCRTS program. Vault will mitigate peak rates and runoff volumes and durations up to 50 year storm. An attempt at the 0.1 cfs peak flow exception was attempted with many iterations of BMP's without success including modelling the buffer area as forest.

Soil & Storm BMP's
Soil is glacial till and not able to infiltrate of any significance. See report by the Galli Group included in appendix. Several dispersion trenches are proposed to direct runoff towards buffer and Champagne Creek. Currently we propose 3 building roof areas directed to trenches. Overflow from these are directed to the Detention Tank. See preliminary engineering plans for this configuration.

## B. Minimum Requirements:

Requirement No 1: Discharge at Natural Location
Yes, all site runoff will continue to drain into Champagne Creek from either the detention vault which mitigates peak flows and the dispersion trenches. Champagne Creek is a permanently flowing drainage. It is fish bearing downstream, but not at this project site.

Requirement No 2: Offsite Analysis
Upstream
Champagne Creek watershed which flows through site has a 75 acre tributary basin per our hydrology calculations we did for culvert sizing. The 100-year storm would produce about 67 cf/s of water.

Downstream

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Please see the attached Downstream Analysis of Champagne Creek in Appendix for ¼ mile downstream Inspection in the late fall of 2015.

Requirement No 3: Flow Control
Vault Required
A level 2 Storm Vault is proposed to meet flow control requirements. Attempts were made at the 0.1 cfs exception. Discussion with City staff is needed to determine it's feasible for the Dispersion trenches to be considered "fully dispersed since their flowpath length exceeds 50 feet.

Dispersion
Dispersion trenches are proposed as shown on our preliminary engineering drawing C3.0. As mentioned earlier, the glacial till soils lack any capacity for infiltration as identified by the geotechnical engineering report.

Requirement No 4: Conveyance System
Conveyance calculations can be found in appendix that show 4" and 6" storm pipes have sufficient capacity to convey and contain above and beyond the 25-yr peak flow.

Requirement No 5: Erosion & Sediment Control
Will provide with LSM permit.

Requirement No 6: Maintenance & Operations
Will provide with LSM permit.

Requirement No 7: Financial Guarantees and Liability
Will provide with LSM permit.

Requirement No 8: Water Quality
Required – proposed is 6,600 sf (>5,000) of driveway. See stormfilter on sheet C3.0.

## C. Special Requirements:

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N/A

## Appendix Items

(numbering correlates with Core Requirement Sections)

2. Downstream Analysis

3A. Impervious Area Spreadsheets

3C. KCRTS Site Area Map

3D. KCRTS 0.1 cfs Calculations for reference (0.1 not achieved)

3E. Flow control Sizing calculations (KCRTS Input and Output)

3F. LID Feasibility Worksheet

4a. Culvert Design
- Culvert Basin Hydrology
- Culvert Sizing hydraulic calculations
- Open Bottom single arch Culvert Specification from Contech

4b. Sample Conveyance System calculations

Also see
9. Geotechnical Soil Report by Galli Group

# Appendix 3a
## Simple Site Impervious Calculator
## preliminary

Kirkland Cottages - 7845 NE 122nd Place, Kirkland, WA 98034 - CES #1430

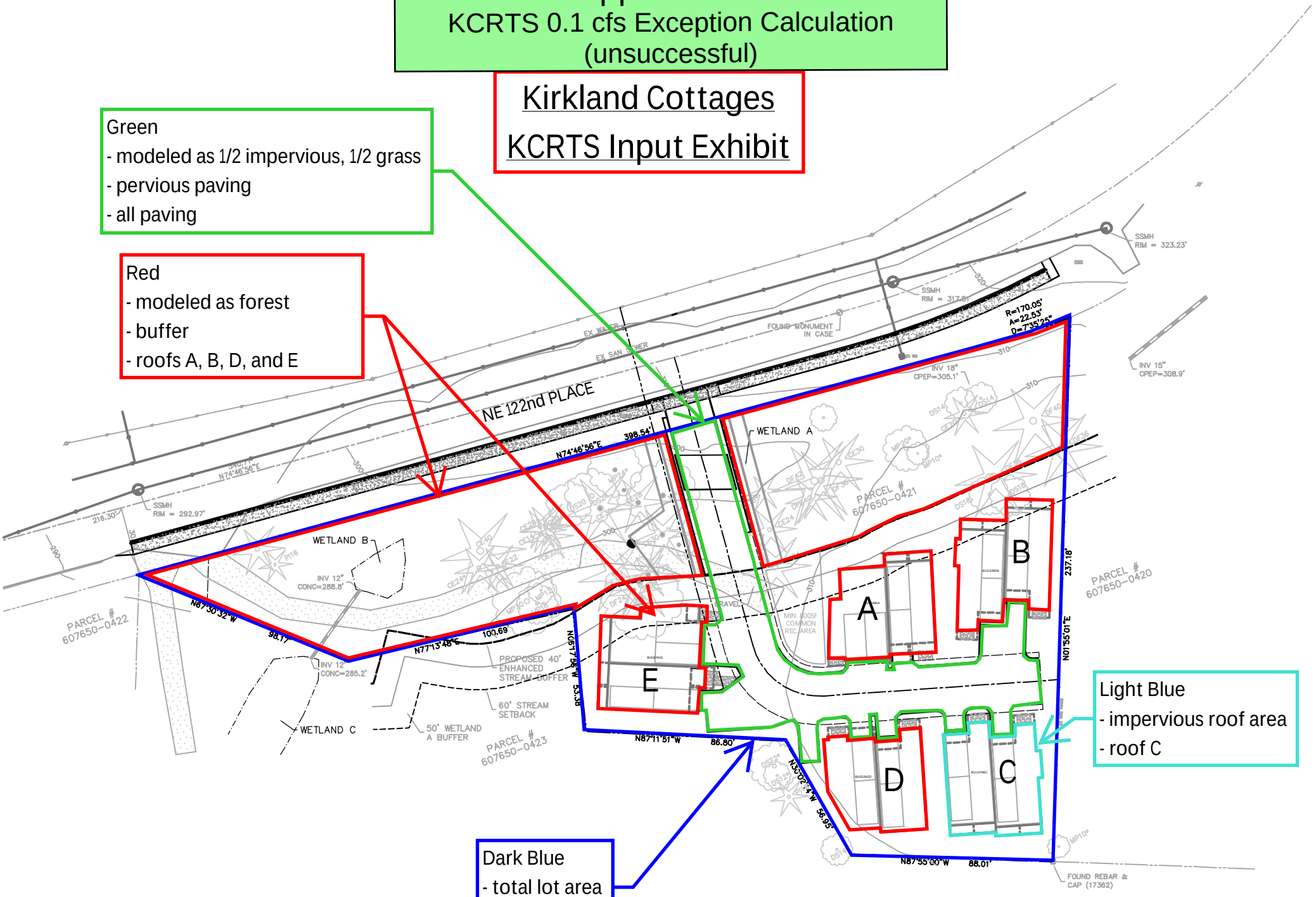
| | | |
|---|---|---|
| Gross Site area | 46,754 | sf - measured survey (survey has misprint of numbe |
| | 1.073 | acres |
| | | |
| Existing Impervious Area | | |
| Ex House | 2,100 | sf |
| Ex driveway, on-site | 2,700 | sf |
| Ex carport/sheds | 1,500 | sf |
| Ex dog run | 500 | sf |
| Ex shed in corner of lot | 100 | sf |
| total existing = | 6,900 | sf |
| | | |
| Proposed Impervious Area (on-site) | | |
| Building A | 2,078 | sf |
| Building B | 2,145 | sf |
| Building C | 2,109 | sf |
| Building D | 1,963 | sf |
| Building E | 2,201 | sf |
| Driveway, on-site | 6,646 | sf from architecture |
| Bridge (part on either side that is not pavemer | 800 | sf |
| total proposed = | 17,942 | |
| | | |
| New vs Replaced impervious area | | |
| total replaced = | 6,900 | |
| total new = | 11,042 | |
| total new + replaced = | 17,942 | |

# Appendix 3d
## KCRTS 0.1 cfs Exception Calculation (unsuccessful)

## Kirkland Cottages
## KCRTS Input Exhibit

Green
- modeled as 1/2 impervious, 1/2 grass
- pervious paving
- all paving

Red
- modeled as forest
- buffer
- roofs A, B, D, and E




Light Blue
- impervious roof area
- roof C

Dark Blue
- total lot area
- 46,754 sf

# Appendix 3d
## KCRTS 0.1 cfs Exception Calculation (unsuccessful)

0.171 cfs developed, mitigated
- 0.087 cfs pre-developed
0.084 cfs < 0.1 cfs threshold

```
                                    KCRTS Command
                                    -------------
                                CREATE a new Time Series
                                ------------------------
                            Production of Runoff Time Series
    Project Location : Sea-Tac
     Computing Series : predev.tsf
Regional Scale Factor :    1.00
            Data Type : Reduced
Creating Hourly Time Series File
                        Loading Time Series
File:C:\KC_SWDM\KC_DATA\STTF60R.rnf   :
Till Forest               1.07 acres
                       --------------
         Total Area :    1.07 acres
Peak Discharge:  0.087 CFS at  9:00 on Jan  9 in Year 8
                                          Storing Time Series
File:predev.tsf   :
                              Time Series Computed

                                    KCRTS Command
                                    -------------
                                CREATE a new Time Series
                                ------------------------
                            Production of Runoff Time Series
    Project Location : Sea-Tac
     Computing Series : dev.tsf
Regional Scale Factor :    1.00
            Data Type : Reduced
Creating Hourly Time Series File
                        Loading Time Series
File:C:\KC_SWDM\KC_DATA\STTF60R.rnf   :
Till Forest               0.48 acres
                        Loading Time Series
File:C:\KC_SWDM\KC_DATA\STTG60R.rnf   :
Till Grass                0.18 acres
                        Loading Time Series
File:C:\KC_SWDM\KC_DATA\STEI60R.rnf   :
Impervious                0.41 acres
                       --------------
         Total Area :    1.07 acres
Peak Discharge:  0.267 CFS at  6:00 on Jan  9 in Year 8
                                             Storing Time Series
File:dev.tsf   :
                              Time Series Computed

                                    KCRTS Command
                                    -------------
                                CREATE a new Time Series
                                ------------------------
                            Production of Runoff Time Series
    Project Location : Sea-Tac
     Computing Series : mitdev.tsf
```

pre-developed condition

buffer

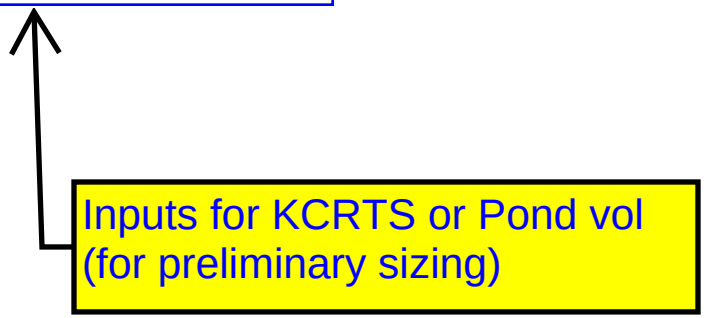
developed, non-mitigated condition

```
Regional Scale Factor :    1.00
            Data Type : Reduced
Creating Hourly Time Series File
                     Loading Time Series
File:C:\KC_SWDM\KC_DATA\STTF60R.rnf   :
Till Forest              0.68 acres
                     Loading Time Series
File:C:\KC_SWDM\KC_DATA\STTG60R.rnf   :
Till Grass               0.25 acres
                     Loading Time Series
File:C:\KC_SWDM\KC_DATA\STEI60R.rnf   :
Impervious               0.15 acres
                      --------------
         Total Area :    1.07 acres
Peak Discharge:  0.171 CFS at  6:00 on Jan  9 in Year 8
                                        Storing Time Series
File:mitdev.tsf   :
                            Time Series Computed

                                KCRTS Command
                                -------------
                          Enter the Analysis TOOLS Module
                          -------------------------------

                              Analysis Tools Command
                              ----------------------
                        Compute PEAKS and Flow Frequencies
                        ----------------------------------
                                        Loading Time Series
File:predev.tsf   :
          Flow Frequency Analysis
          -------------------------------------------------------
  Time Series File:predev.tsf
  Project Location:Sea-Tac

                              Analysis Tools Command
                              ----------------------
                        Compute PEAKS and Flow Frequencies
                        ----------------------------------
                                           Loading Time Series
File:dev.tsf   :
          Flow Frequency Analysis
          -------------------------------------------------------
  Time Series File:dev.tsf
  Project Location:Sea-Tac

                              Analysis Tools Command
                              ----------------------
                        Compute PEAKS and Flow Frequencies
                        ----------------------------------
                                        Loading Time Series
File:mitdev.tsf   :
          Flow Frequency Analysis
          -------------------------------------------------------
```

developed, mitigated condition

# Appendix 3e
## Vault Sizing Impervious inputs

| KCRTS DETENTION VAULT IMPERVIOUS CALCULATOR | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| Kirkland Cottages - KCRTS Impervious Spreadsheet | | | | | | | |
| | | | | CES #1430 | | | |
| | sf | ac | | | | | |
| Detention Site Area (FOR SIZING) | 26,200 | 0.601 | | | | | |
| | | | | Impervious Areas = true values used, NOT 50% | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| Soil Type | till | (assumed) | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| *Desc* | *Gross Area* | | *impervious area* | *Grass* | *Forest* | | *comments* |
| | | | | | | | |
| Post Development-BMP mitigation applied | | | | | | | |
| | | | | | | | |
| Detention Vault "Site" Area | 26,200 | (gross lot) | | | | | |
| Building A | | | 1,040 | 1,040 | | | building Imperv is split 50/50 per table 1.2.3.C |
| Building B | | | 1,070 | 1,070 | | | building Imperv is split 50/50 per table 1.2.3.C |
| Building C | | | 2,108 | | | | |
| Building D | | | 1,962 | | | | |
| Building E | | | 1100 | 1100 | | | building Imperv is split 50/50 per table 1.2.3.C |
| Paved Area | | | 6,421 | | | | |
| Detention Vault Imperv | | | 900 | | | | |
| Subtotals | | 17,811 | 14,601 | 3,210 | | | |
| Left over Grass Calc | | | | 8,389 | | | |
| | | | 14,601 | 11,599 | 0 | 26,200 | SF |
| Total Areas | | | 0.335 | 0.266 | 0.000 | 0.601 | AC |
| | | | Impervious | Grass | Forest | | |



# Appendix 3e
## Detention Volume: level 2 preliminary sizing

## Pondcalc Worksheet

Instructions:

1 Enter site information in the yellow highlighted cells
2 Verify no error message is displayed
3 Results are displayed in Green Box

*Note: pondcalc will not work for negative landcover conversions.
pondcalc does not handle existing EI or TG very well.

**Disclaimer: This spreadsheet is provided without warranty of any kind. Use this spreadsheet at your own risk. All facility sizes should be verified using KCRTS software.**

| | | |
|---|---|---|
| Rainfall Region | ST | {either ST or LA see rainfall regions map} |
| Scale Factor: | 1.00 | { 0.8 - 1.2 see rainfall regions map} |
| FC Level: | 2 | { 1, 2, or 3 see flow control app map} |

| Predeveloped acres | Landcover type | Postdeveloped acres | Adjusted Acres converted cover | Error Messages |
|---|---|---|---|---|
| 0.601 | TF | | 0.601 | |
| 0 | TP | | 0 | |
| | TG | 0.266 | 0.266 | |
| | EI | 0.335 | 0.335 | |

| Acreage Check: | post | pre |
|---|---|---|
| gross | 0.601 | 0.601 |
| adjusted | 0.601 | 0.601 |

**Storage Estimate:**

**3.3 inches per converted acre**
**3.3 inches per gross acre**
**0.2 ac-ft**
**7,282 cubic-ft**

Peak Flow Calc

CES #1430 Chandler Townhomes Culvert sheet 1 of 2

$A_t$ = 75 acres (RSA 6-8)
$A_1$ = 73.35 acres (single-family residential)
$A_2$ = 0.96 acres (multi-unit residential)
$A_3$ = 0.69 acres

Description of flowpath segments for $T_c$

| | | | |
|---|---|---|---|
| $L_1$ = lawn = 400 ft | $S_1$ = 0.025 | $K_1$ = 7.0 |
| $L_2$ = low-sloped pipe = 1000 ft | $S_2$ = 0.02 | $K_2$ = 20.0 |
| $L_3$ = steep pipe = 700 ft | $S_3$ = 0.057 | $K_3$ = 20.0 |
| $L_4$ = open waterway = 1100 ft | $S_4$ = 0.055 | $K_4$ = 15.0 |

Appendix 4a
hydrology-Champagne Creek
100-year storm flow estimate

$Q = CIA$

$$C = \frac{C_1 A_1 + C_2 A_2 + C_3 A_3 + C_4}{A_t}$$

from WSDOT Hydraulics Manual, March 2004:
- single-family residential 10-yr $C$ = 0.5
  upsize by 25% for 100 yr $C_{1-100}$ = ~~0.6~~ 0.63
- multi-units attached 10-yr $C_{2-10}$ = 0.7
  upsize by 25% for 100 yr $C_{2-100}$ = 0.88
- park 10-yr $C_{3-10}$ = ~~0.25~~ 0.25
  upsize by 25% for 100 yr $C_{3-100}$ = 0.31

$$C = \frac{(0.63 * 73.35) + (0.88 * 0.96) + (0.31 * 0.69)}{75}$$

$$= \frac{46.211 + 0.845 + 0.214}{75} = \frac{47.27}{75} = 0.63$$

$I_R = (P_R)(i_R)$

$P_R = P_{100}$ = 3.53 in from isopluvial
$i_R$ = unit peak rainfall intensity factor
$= (a_R)(T_c)^{-b_R}$

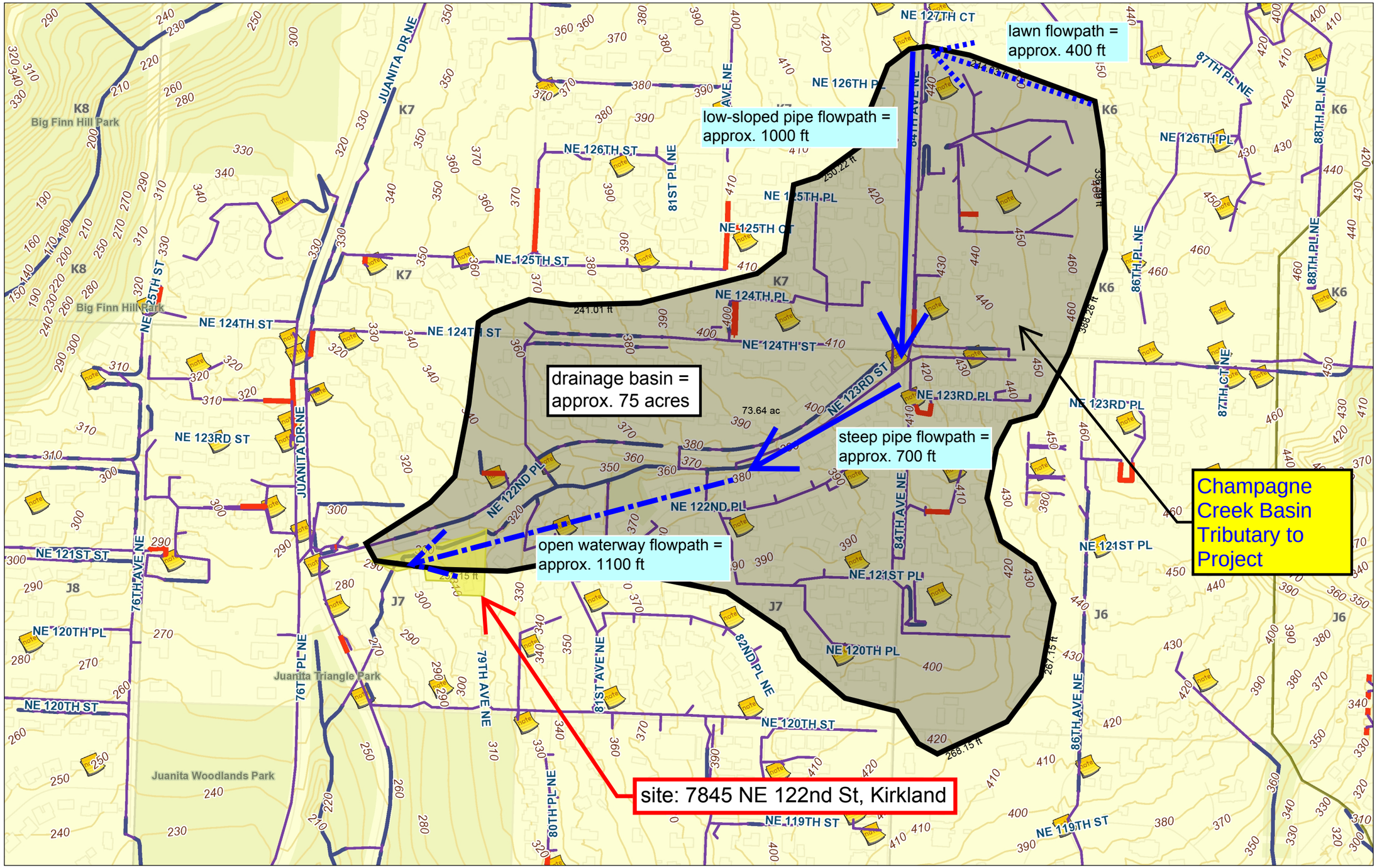
$a_r = a_{100}$ = 2.61 } from Table 3.2.1.B
$b_r = b_{100}$ = 0.63 } 2009 KCSWDM

$T_C = T_1 + T_2 + T_3 + T_4$

$T = \frac{L}{60V}$ $\quad V = K_r \sqrt{S_r}$

# Chandler Townhomes - 7845 NE 122nd Place

drainage basin area exhibit
flowpath distance exhibit




## Legend

- Olympic Pipeline Corridor
- Pipes Tanks Etc
  - SW Pipe
  - SW Tank or Vault
- Stream Ditch Etc
- Storm Record Drawing
- Flow Control
  - Level 1
  - Level 2
- Contours 10 Feet
- City Limits
- Cross Kirkland Corridor
- Regional Rail Corridor
- Streets
- Grid
- QQ Grid
- Buildings
- Lakes
- Parks
- Schools

1: 4,000

0.1 0 0.06 0.1 Miles

NAD_1983_StatePlane_Washington_North_FIPS_4601_Feet



**Notes**

lawn: 400 ft

$K_1 = 7.0$ lawn from Table 3.2.1.C 2009 KCSWDM

$S_1$ = slope = 0.025 ft/ft

$V_1 = K_1\sqrt{S_1} = 7.0\sqrt{0.025} = 1.11$ ft/sec

$T_1 = \frac{400 \text{ ft}}{(60 \text{ sec/min})(1.11 \text{ ft/sec})} = 6.0$ min

Appendix 4a
hydrology-Champagne Creek
100-year storm flow estimate

low-sloped-pipe: 1000 ft

$K_2 = 20.0$

$S_2 = 0.02$ ft/ft

$V_2 = 20\sqrt{0.02} = 2.83$ ft/s

$T_2 = \frac{1000 \text{ ft}}{60 * 2.83} = 5.9$ min

steep pipe: 700 ft

$K_3 = 20.2$

$S_3 = 0.057$ ft/ft

$V_3 = K_3\sqrt{S_3} = 20\sqrt{0.057} = 4.8$ ft/s

$T_3 = \frac{700}{60 * 4.8} = 2.43$ min

open waterway: 1100 ft

$K_4 = 15.0$

$S_4 = 0.055$ ft/ft

$V_4 = K_4\sqrt{S_4} = 15.0\sqrt{0.055} = 3.5$ ft/s

$T_4 = \frac{1100}{60(3.5)} = 5.2$ min

$T_c = 6.0 + 5.9 + 2.4 + 5.2 = 19.5$ minutes

$i_R = i_{100} = (a_{100})(T_c)^{-b_r}$

$= (2.61)(19.5)^{-0.63}$

$= (2.61)(0.154) = 0.40$

$I_{100} = (P_{100})(i_{100}) = (3.53)(0.40) = \underline{1.42}$

$Q = CIA = (0.63)(1.42)(75) = \underline{67 \text{ cfs}}$

100 year storm flow estimate

Appendix 4a
hydrology-Champagne Creek
100-year storm flow estimate

Manual 2004

| Type of Cover | Flat | Rolling 2%-10% | Hilly Over 10% |
|---|---|---|---|
| Pavement and Roofs | 0.90 | 0.90 | 0.90 |
| Earth Shoulders | 0.50 | 0.50 | 0.50 |
| Drives and Walks | 0.75 | 0.80 | 0.85 |
| Gravel Pavement | 0.50 | 0.55 | 0.60 |
| City Business Areas | 0.80 | 0.85 | 0.85 |
| Suburban Residential | 0.25 | 0.35 | 0.40 |
| Single Family Residential | 0.30 | 0.40 | 0.50 |
| Multi Units, Detached | 0.40 | 0.50 | 0.60 |
| Multi Units, Attached | 0.60 | 0.65 | 0.70 |
| Lawns, Very Sandy Soil | 0.05 | 0.07 | 0.10 |
| Lawns, Sandy Soil | 0.10 | 0.15 | 0.20 |
| Lawns, Heavy Soil | 0.17 | 0.22 | 0.35 |
| Grass Shoulders | 0.25 | 0.25 | 0.25 |
| Side Slopes, Earth | 0.60 | 0.60 | 0.60 |
| Side Slopes, Turf | 0.30 | 0.30 | 0.30 |
| Median Areas, Turf | 0.25 | 0.30 | 0.30 |
| Cultivated Land, Clay and Loam | 0.50 | 0.55 | 0.60 |
| Cultivated Land, Sand and Gravel | 0.25 | 0.30 | 0.35 |
| Industrial Areas, Light | 0.50 | 0.70 | 0.80 |
| Industrial Areas, Heavy | 0.60 | 0.80 | 0.90 |
| Parks and Cemeteries | 0.10 | 0.15 | 0.25 |
| Playgrounds | 0.20 | 0.25 | 0.30 |
| Woodland and Forests | 0.10 | 0.15 | 0.20 |
| Meadows and Pasture Land | 0.25 | 0.30 | 0.35 |
| Pasture with Frozen Ground | 0.40 | 0.45 | 0.50 |
| Unimproved Areas | 0.10 | 0.20 | 0.30 |

**Runoff Coefficients for the Rational Method — 10-Year Return Frequency**

*Figure 2-4.2*

### 2-5.3 Time of Concentration

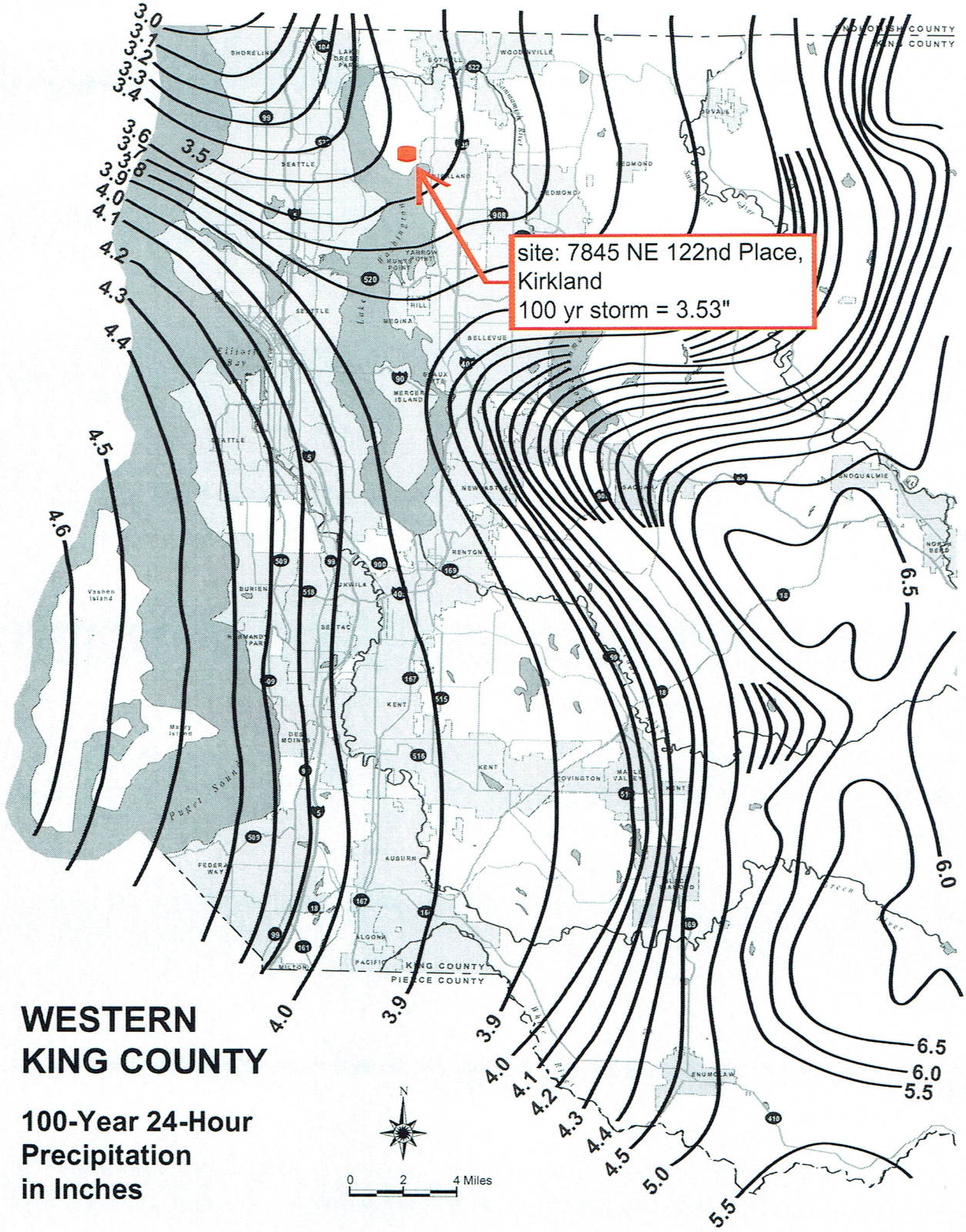
If rainfall is applied at a constant rate over a drainage basin, it would eventually produce a constant peak rate of runoff. The amount of time that passes from the moment that the constant rainfall begins to the moment that the constant rate of runoff begins is called the time of concentration. This is the time required for the surface runoff to flow from the most hydraulically remote part of the drainage basin to the location of concern.

Actual precipitation does not fall at a constant rate. A precipitation event will begin with small rainfall intensity then, sometimes very quickly, build to peak intensity and eventually taper down to no rainfall. Because rainfall intensity is variable, the time of concentration is included in the rational method so that the designer can determine the

Appendix 4a
hydrology-Champagne Creek
100-year storm flow estimate



FIGURE 3.2.1.D 100-YEAR 24-HOUR ISOPLUVIALS



Appendix 4a
hydrology-Champagne Creek
100-year storm flow estimate



**TABLE 3.2.1.A RUNOFF COEFFICIENTS - "C" VALUES FOR THE RATIONAL METHOD**

| General Land Covers | | Single Family Residential Areas* | |
|---|---|---|---|
| Land Cover | $C$ | Land Cover Density | $C$ |
| Dense forest | 0.10 | 0.20 DU/GA (1 unit per 5 ac.) | 0.17 |
| Light forest | 0.15 | 0.40 DU/GA (1 unit per 2.5 ac.) | 0.20 |
| Pasture | 0.20 | 0.80 DU/GA (1 unit per 1.25 ac.) | 0.27 |
| Lawns | 0.25 | 1.00 DU/GA | 0.30 |
| Playgrounds | 0.30 | 1.50 DU/GA | 0.33 |
| Gravel areas | 0.80 | 2.00 DU/GA | 0.36 |
| Pavement and roofs | 0.90 | 2.50 DU/GA | 0.39 |
| Open water (pond, lakes, wetlands) | 1.00 | 3.00 DU/GA | 0.42 |
| | | 3.50 DU/GA | 0.45 |
| | | 4.00 DU/GA | 0.48 |
| | | 4.50 DU/GA | 0.51 |
| | | 5.00 DU/GA | 0.54 |
| | | 5.50 DU/GA | 0.57 |
| | | 6.00 DU/GA | 0.60 |

* Based on average 2,500 square feet per lot of impervious coverage.
For combinations of land covers listed above, an area-weighted "$C_c$:x $A_t$" sum should be computed based on the equation $C_c$: x $A_t$ = ($C_1$ x $A_1$) + ($C_2$ x $A_2$) + ...+($C_n$ x $A_n$), where $A_s$ = ($A_1$ + $A_2$ + ...+$A_n$), the total drainage basin area.

**TABLE 3.2.1.B COEFFICIENTS FOR THE RATIONAL METHOD "$i_R$" EQUATION**

| Design Storm Return Frequency | $a_R$ | $b_R$ |
|---|---|---|
| 2 years | 1.58 | 0.58 |
| 5 years | 2.33 | 0.63 |
| 10 years | 2.44 | 0.64 |
| 25 years | 2.66 | 0.65 |
| 50 years | 2.75 | 0.65 |
| 100 years | 2.61 | 0.63 |

**TABLE 3.2.1.C $k_R$ VALUES FOR $T_t$ USING THE RATIONAL METHOD**

| Land Cover Category | $k_R$ |
|---|---|
| Forest with heavy ground litter and meadow | 2.5 |
| Fallow or minimum tillage cultivation | 4.7 |
| Short grass pasture and lawns | 7.0 |
| Nearly bare ground | 10.1 |
| Grassed waterway | 15.0 |
| Paved area (sheet flow) and shallow gutter flow | 20.0 |

# Appendix 4a
## Normal flow depth in Creek
## 100-year storm=67 cfs

tmp#1

Channel Calculator

Given Input Data:

| | |
|---|---|
| Shape | Rectangular |
| Solving for | Depth of Flow |
| Flowrate | 67.0000 cfs |
| Slope | 0.0460 ft/ft |
| Manning's n | 0.0280 |
| Height | 120000.0000 in |
| Bottom width | 72.0000 in |

Computed Results:

| | |
|---|---|
| Depth | 13.4714 in |
| Velocity | 9.9470 fps |
| Full Flowrate | 67.0000 cfs |
| Flow area | 6.7357 ft2 |
| Flow perimeter | 98.9428 in |
| Hydraulic radius | 9.8030 in |
| Top width | 72.0000 in |
| Area | 6.7357 ft2 |
| Perimeter | 98.9428 in |
| Percent full | 100.0000 % |

Critical Information

| | |
|---|---|
| Critical depth | 18.8493 in |
| Critical slope | 0.0172 ft/ft |
| Critical velocity | 7.1090 fps |
| Critical area | 9.4247 ft2 |
| Critical perimeter | 109.6986 in |
| Critical hydraulic radius | 12.3716 in |
| Critical top width | 72.0000 in |
| Specific energy | 2.6602 ft |
| Minimum energy | 2.3562 ft |
| Froude number | 1.6551 |
| Flow condition | Supercritical |

depth of flow=13.5"

given:
assume rectangular flow
as first try
72" wide channel
Q=67 cfs
Mannings=0.028

# Appendix 4a
## Open bottom Culvert by Contech
## Preliminary Single radius Arch

**TABLE 22. MULTI-PLATE® ARCHES**

| Dimensions | | | | | Nominal Arc Length |
|---|---|---|---|---|---|
| Span, Feet | Rise, Ft.-In. | Waterway Area Ft.² | Rise/Span Ratio | Radius Inches | Pi |
| 6.0 | 1-10 | 7.9 | 0.30 | 41 | 27 |
| | 2-4 | 10.0 | 0.38 | 37 | 30 |
| | 3-2 | 15.0 | 0.53 | 36 | 36 |
| 7.0 | 2-5 | 12.1 | 0.34 | 45 | 33 |
| | 2-10 | 14.9 | 0.41 | 43 | 36 |
| | 3-8 | 20.4 | 0.52 | 42 | 42 |
| 8.0 | 2-11 | 17.0 | 0.36 | 51 | 39 |
| | 3-4 | 20.3 | 0.42 | 49 | 42 |
| | 4-2 | 26.6 | 0.52 | 48 | 48 |
| 9.0 | 2-11 | 19.2 | 0.33 | 59 | 42 |
| | 3-11 | 26.5 | 0.43 | 55 | 48 |
| | 4-8 | 33.6 | 0.52 | 54 | 54 |
| 10.0 | 3-6 | 25.4 | 0.35 | 64 | 48 |
| | 4-5 | 33.5 | 0.44 | 61 | 54 |
| | 5-3 | 41.4 | 0.52 | 60 | 60 |
| 11.0 | 3-6 | 27.8 | 0.32 | 73 | 51 |
| | 4-6 | 36.9 | 0.41 | 68 | 57 |
| | 5-9 | 50.0 | 0.52 | 66 | 66 |
| 12.0 | 4-1 | 35.3 | 0.34 | 78 | 57 |
| | 5-0 | 45.2 | 0.42 | 73 | 63 |
| | 6-3 | 59.4 | 0.52 | 72 | 72 |
| 13.0 | 4-1 | 38.1 | 0.33 | 87 | 60 |
| | 5-1 | 48.9 | 0.40 | 81 | 66 |
| | 6-9 | 69.7 | 0.52 | 78 | 78 |
| 14.0 | 4-8 | 47.0 | 0.31 | 91 | 66 |
| | 5-7 | 58.5 | 0.38 | 86 | 72 |
| | 7-3 | 80.7 | 0.44 | 84 | 84 |
| 15.0 | 4-8 | 48.9 | 0.52 | 101 | 69 |
| | 5-8 | 62.8 | 0.33 | 93 | 75 |
| | 6-7 | 74.8 | 0.44 | 91 | 81 |
| | 7-9 | 92.6 | 0.52 | 90 | 90 |
| 16.0 | 5-3 | 60.1 | 0.31 | 105 | 75 |
| | 7-1 | 86.2 | 0.42 | 97 | 87 |
| | 8-4 | 105.3 | 0.52 | 96 | 96 |
| 17.0 | 5-3 | 63.4 | 0.31 | 115 | 78 |
| | 7-2 | 91.9 | 0.42 | 103 | 90 |
| | 8-10 | 118.8 | 0.52 | 102 | 102 |
| 18.0 | 5-9 | 74.8 | 0.32 | 119 | 84 |
| | 7-8 | 104.6 | 0.43 | 109 | 96 |
| | 8-11 | 126.0 | 0.50 | 108 | 105 |
| 19.0 | 6-4 | 87.1 | 0.33 | 123 | 90 |
| | 8-3 | 118.1 | 0.43 | 115 | 102 |
| | 9-5 | 140.7 | 0.50 | 114 | 111 |
| 20.0 | 6-4 | 91.0 | 0.32 | 133 | 93 |
| | 8-3 | 124.4 | 0.42 | 122 | 105 |
| | 10-0 | 156.3 | 0.50 | 120 | 117 |
| 21.0 | 6-11 | 104.6 | 0.33 | 137 | 99 |
| | 8-10 | 139.2 | 0.42 | 128 | 111 |
| | 10-6 | 172.6 | 0.50 | 126 | 123 |
| 22.0 | 6-11 | 109.3 | 0.32 | 146 | 102 |
| | 8-11 | 145.9 | 0.40 | 135 | 114 |
| | 11-0 | 189.8 | 0.50 | 132 | 129 |
| 23.0 | 8-0 | 133.6 | 0.35 | 147 | 111 |
| | 9-10 | 171.1 | 0.43 | 140 | 123 |
| | 11-6 | 207.8 | 0.50 | 138 | 135 |
| 24.0 | 8-6 | 149.4 | 0.36 | 152 | 117 |
| | 10-4 | 188.3 | 0.43 | 146 | 129 |
| | 12-0 | 226.6 | 0.50 | 144 | 141 |
| 25.0 | 8-7 | 155.6 | 0.34 | 160 | 120 |
| | 10-10 | 206.3 | 0.43 | 152 | 135 |
| | 12-6 | 246.2 | 0.50 | 150 | 147 |
| 26.0 | 8-7 | 161.4 | 0.33 | 169 | 123 |
| | 11-0 | 214.9 | 0.42 | 158 | 138 |
| | 13-1 | 266.7 | 0.50 | 156 | 153 |

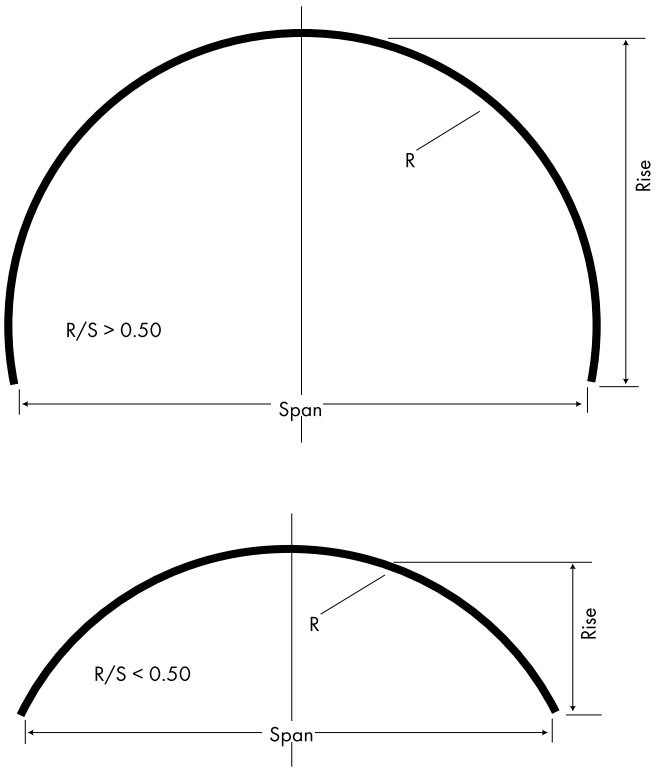



**Figure 6. Arch**

**MULTI-PLATE Arch Pedestrian Underpass**

Notes:
1. Dimensions are to inside crests of corrugations are are subject to manufacturing tolerances.
2. To determine proper gage, use Table 24 and design information found on Pages 13-18.
3. For additional arch sizes, see your Contech® representative.